TRANSMITTING SIGNALS OVER INTERCONNECT CARRYING DIRECT CURRENT FROM POWER SUPPLY TO ELECTRONIC DEVICE

BACKGROUND

Electronic devices, such as computer peripherals like printers, may consume different amounts of power depending on the tasks that they are currently performing. For example, when inkjet and laser printers, as well as other types of image-forming images, are actually printing, they usually consume much more power than when they are not printing. Power supplies for such electronic devices thus provide different amounts of power depending on the tasks being performed by these devices.

To adjust the amount of voltage and/or power provided by the power supplies of such electronic devices, the devices may have internal regulators that regulate the voltage and/or power provided to the devices. This is because many power supplies are manufactured inexpensively, and therefore have unregulated, loosely regulated, or not tightly regulated, nominal voltages and/or powers. However, including regulators within electronic devices can be expensive. For electronic devices that have low profit margins, such as consumer electronic-type devices, as well as some types of image-forming devices, there may be resistance to including such regulators within the electronic devices.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings referenced herein form a part of the specification. Features shown in the drawing are meant as illustrative of only some

embodiments of the invention, and not of all embodiments of the invention, unless otherwise explicitly indicated.

FIG. 1 is a diagram of an embodiment of a system, according to an embodiment of the invention.

FIG. 2 is a diagram of the embodiment of the system that is more detailed than but consistent with the system of FIG. 1, according to an embodiment of the invention.

FIGs. 3 and 4 are diagrams of different embodiments of communication circuits that may be employed in the systems of FIGs. 1 and 2, according to varying embodiments of the invention.

FIGs. 5, 6, and 7 are diagrams of different embodiments of decoder circuits that may be employed in the embodiments of the systems of FIGs. 1 and 2, according to varying embodiments of the invention.

FIG. 8 is a flowchart of an embodiment of a method, according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

In the following detailed description of exemplary embodiments of the invention, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific exemplary embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice these embodiments of the invention. Other embodiments may be utilized, and logical, mechanical, and other changes may be made without departing from the spirit or scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims.

Overview

FIG. 1 shows a system 100, according to an embodiment of the invention. The system 100 includes an electronic device 102 and a power supply 104. The electronic device 102 performs a principal functionality. For

instance, the principal functionality may be image formation, such that the electronic device 102 is an image-forming device, like an inkjet printer, a laser printer, or another type of printing device. The power supply 104 receives alternating current (AC) from a power source 112 and converts the AC to direct current (DC) to power the electronic device 102 so that it can perform its principal functionality. The power supply 104 may be internal or external to the electronic device 102.

The DC is provided by the power supply 104 to the electronic device 102 via an interconnect 106, which may be an insulated cable. The interconnect 106 includes a second conductor 108 and a first conductor 110, the former on which the DC is actually provided, and the latter, which is the return path and which may be connected to ground. The interconnect 106 may also have more than two conductors. The second conductor 108 also may be referred to as the DC rail of the interconnect 106. The power supply 104 receives the AC from the power source 112 via another power line 114. The power line 114 may have two, three, or more conductors, which are not specifically shown in FIG. 1. The power source 112 may, for instance, be a wall outlet, into which the power line 114 is plugged. Alternatively, the power line 114 may not be present, such that the power supply 104 itself directly plugs into the power source 112.

In a different embodiment of the invention, the power supply 104 may be considered to be one stage of a larger power supply, such that it converts DC previously converted from AC by a previous power supply stage to the DC used to power the electronic device 102. In still another embodiment, the power source 112 may provide DC instead of AC, such as when the power source 112 is a battery, such that the power supply 104 may convert such DC to the DC used to power the electronic device. That is, the power line 114 may supply DC or AC, although it is substantially described herein for sake of simplicity as supplying AC.

The electronic device 102 is able to send communication signals over the interconnect 106 to the power supply 104. For example, the electronic device 102 may indicate to the power supply 104 the level of voltage and/or power that is needed, the type of voltage and/or power that is to be supplied to the

electronic device 102, the type of voltage and/or power regulation that is provided, as well as other types of communication signals, such as feedback signals and other types of signals. These feedback signals and other types of signals may include signals for controlling voltage and/or power modes, as well as signals regarding peak and/or brownout conditions. The power supply 104 may also be able to send communication signals over the interconnect 106 to the electronic device 102.

The communication signals transmitted over the interconnect 106 may be high-frequency signals, such as high-frequency square, sinusoidal, or triangular signals, as well as other types of waveforms and high-frequency signals. For example, the high-frequency signals may be pulse-width modulation (PWM) signals, or other types of high frequency pulse signals, to encode a desired message. As used herein, the term waveform can in fact encompass multiple waveforms at different frequencies superimposed upon one another, as may be appreciated by those of ordinary skill within the art. Because the DC provided to the electronic device 102 on the interconnect 106 is inherently transmitted at a low frequency, the high-frequency nature of the communication signals allows the communication signals to be sent concurrently with the DC provided to the electronic device 102 on the conductor 108.

System having electronic device and power supply

FIG. 2 shows the system 100 of FIG. 1 in more detail, according to an embodiment of the invention. As in FIG. 1, the system 100 includes the electronic device 102 and the power supply 104 connected to one another through the interconnect 106, where the power supply 104 is connected to the power source 112 via the power line 114. The power supply 104 converts alternating current (AC) from the power source 112 transmitted over the power line 114 to direct current (DC), and provides the DC over the interconnect 106 to the electronic device 102 so that the device 102 is able to perform its principal functionality. The electronic device 102 is able to send communication signals over the interconnect 106 to the power supply 104. For example, in one embodiment the communication signals may be sent over the second conductor

108 of the interconnect 106. The power supply 104 may also be able to send communication signals to the electronic device 102. Whereas the power supply 104 and the interconnect 106 are depicted in FIG. 2 as external to the electronic device 102, in an alternate embodiment both may be internal to the device 102.

The electronic device 102 includes principal components 202, a decoder circuit 204, a communication circuit 206, and an inductor 208. The principal components 202 include those components that enable the electronic device 102 to perform its principal functionality. For instance, the principal components 202 may be or include image-forming components, such as an inkjet-printing mechanism or a laser-printing mechanism, so that the electronic device 102 is able to perform image formation on media. The principal components 202 utilize the DC received over the interconnect 106 to provide such principal functionality. The inductor 208 is more generally an isolating component or a high-frequency filter, and substantially prevents (or, isolates) the high-frequency communication signals transmitted over the interconnect 106 from interfering with the DC provided to the principal components 202 so that they can perform the principal functionality of the electronic device 102. That is, the inductor 208 attenuates the transmission of high-frequency communication signals to the components 202.

The communication circuit 206 of the electronic device 102 includes a signal generator 214 and a coupler 212. The signal generator 214 receives the information that the principal components 202 of the electronic device 102. In turn, the signal generator 214 generates communication signals to transmit this information to the power supply 104, encoding the information in the process. The communication signals are coupled to the second conductor 108 by the coupler 212, and thus are sent over the second conductor 108 of the interconnect 106 to the power supply 104.

The decoder circuit 204 of the electronic device 102 includes a signal detector 210. The decoder circuit 204 is denoted with dotted lines in FIG. 2 to indicate that it is optional, and does not have to be included within the electronic device 102. The signal detector 210 detects communication signals sent by the

power supply 104 over the interconnect 106, and decodes the signals into information that is then provided to the principal components 202.

The interconnect 106 is depicted in FIG. 2 as including resistors 216 and 218, inductor 219, and a capacitor 222. The interconnect 106 may be treated as a transmission line having resistance, inductance, and capacitance that may be considered when communicating signals over the interconnect 106. As a result, the resistor 216 discretely represents the inherent resistance of the second conductor 108 of the interconnect 106. The resistor 218 likewise discretely represents the inherent resistance of the first conductor 110 of the interconnect 106. The capacitor 222 discretely represents the inherent capacitance between the conductors 108 and 110. The inductor 219 discretely represents the inductance of the conductors 108 and 110. Although the interconnect 106 is depicted in FIG. 2 as being external to both the electronic device 102 and the power supply 104, in differing embodiments of the invention the interconnect 106 may alternatively be internal to either the electronic device 102 or the power supply 104.

The power supply 104 includes principal components 224, a decoder circuit 230, a communication circuit 228, and an inductor 226. The principal components 224 include those components that enable the power supply 104 to convert the AC provided by the power source 112 over the power line 114 into the DC provided to the electronic device 102 over the interconnect 106. The principal components 224 may thus include a transformer. The inductor 226 is more generally an isolating component, or a high-frequency filter, and substantially prevents (or, isolates) the high-frequency communication signals transmitted over the interconnect 106 from interfering with the DC generated by the principal components 224 so that their conversion of AC to DC is not affected. That is, the inductor 226 attenuates the transmission of the high-frequency communication signals to the components 224.

The decoder circuit 230 of the power supply 104 includes a signal detector 232. The signal detector 232 detects communication signals sent by the electronic device 102 over the interconnect 106, and decodes the signals into information that is then provided to the principal components 224. For

example, the high-frequency communication signals sent by the electronic device 102 may encode parameters in accordance with which the principal components 224 convert AC to DC for transmission over the interconnect 106 to the electronic device 102. These parameters may indicate the amount and nature of the power that the electronic device 102 is requesting that the power supply 104 provide.

The communication circuit 228 of the power supply 104 includes a signal generator 236 and a coupler 234. The communication circuit 228 is denoted with dotted lines in FIG. 2 to indicate that it is optional, and does not have to be included within the power supply 104. The signal generator 236 receives the information that the principal components 224 of the power supply 104 wish to transmit to the electronic device 102. In turn, the signal generator 236 generates communication signals that encode this information. The communication signals are coupled to the second conductor 108 by the coupler 234, and thus are sent over the second conductor 108 of the interconnect 106 to the electronic device 102.

Communication circuit

FIGs. 3 and 4 show a communication circuit 300, according to different embodiments of the invention. The communication circuit 300 of FIG. 3 or 4 may implement the communication circuit 206 of the electronic device 102 of FIG. 2, and/or the communication circuit 228 of the power supply 104 of FIG. 2. In general, the communication circuit 300 transmits high-frequency communication signals from the principal components over the interconnect 106, which do not significantly interfere with the direct current (DC) carried by the interconnect 106, because the DC is inherently low frequency. FIG. 3 specifically depicts the coupling of voltage for signal coupling, whereas FIG. 4 specifically depicts magnetic coupling of voltage for signal coupling.

In FIG. 3, the signal generator 302 receives information from the principal components and generates a square waveform, a triangular waveform, a sinusoidal waveform, a pulse-width modulated (PWM) waveform, or another type of waveform, to transmit over the interconnect 106, as indicated by the

reference number 306. This waveform is then coupled to the electric field of the interconnect 106 via the capacitor 304, such that coupling of a voltage is achieved to yield communication signal transmission over the interconnect 106. The capacitor 304 may serve as the coupler 212 or the coupler 234 of FIG. 2. The signal generator 302 is connected between the first conductor 110 and the capacitor 304, which is itself connected to the second conductor 108.

In FIG. 4, the signal generator 302 again generates a type of waveform based on the information that is to sent by the principal components to be transmitted over the power line, as indicated by the reference number 306. The waveform is coupled to the magnetic field of the interconnect 106 via the inductive transformer 404, such that magnetic field coupling, or alternating current (AC) coupling, is achieved to yield communication signal transmission over the interconnect 106. The inductive transformer 404 may serve as the coupler 212 or the coupler 234 of FIG. 2. The signal generator is connected between the first conductor 110 and one side of the inductive transformer 404, whereas the other side of the inductive transformer 404 is connected to the second conductor 108. Alternatively, the waveform may be coupled as a voltage, or injected as a current or as voltage variations, over the second conductor 108. It is noted that, in general, the waveform output by the signal generator 302 can be output as either a voltage source or a current source.

Decoder circuit

FIGs. 5, 6, and 7 show a decoder circuit 500, according to different embodiments of the invention. The decoder circuit 500 of FIG. 5, 6, or 7 may implement the decoder circuit 204 of the electronic device 102 of FIG. 2, and/or may implement the decoder circuit 230 of the power supply 104 of FIG. 2. In general, the decoder circuit 500 receives and decodes high-frequency communication signals over the interconnect 106, which do not significantly interfere with the direct current (DC) carried to the electronic device 102 by the interconnect 106, because the DC is inherently low frequency.

In FIG. 5, the decoder circuit 500 has a signal detector 502 that is able to detect and decode a magnetic field-coupled, a voltage-coupled, a current-

coupled, or an alternating current (AC)-coupled, pulse-width modulated (PWM) or square waveform, from the communication signals received over the interconnect 106. The decoded information is then transmitted to the principal components, as indicated by the reference number 516. The signal detector 502 includes an operational amplifier (op amp) 504, resistors 506 and 510, and capacitors 508 and 512, that are connected together as a basic integrator circuit, such that the decoder circuit 500 can be considered an integrator. The negative input of the op amp 504 have the resistor 506 and the capacitor 508 connected in series to the second conductor 108. Furthermore, the resistor 510 and the capacitor 512 are connected in parallel between the negative input of the op amp 504 and the output of the op amp 504. The output of the op amp 504 is further connected to the principal components, as indicated by the reference number 516. The positive input of the op amp 504 is connected to the first conductor 110.

In FIG. 6, the signal detector 502 of the decoder circuit 500 is able to detect and decode a magnetic field-coupled, or AC-coupled, triangular waveform from the communication signals received over the interconnect 106. As before, the decoded information is transmitted to the principal components, as indicated by the reference number 516. The signal detector 502 includes a capacitor 604 and an inverter 602, such as with hysteresis, connected in series between the second conductor 108 and the principal components, as indicated by the reference number 516.

In FIG. 7, the signal detector 502 of the decoder circuit 500 is able to detect and decode a magnetic field-coupled, or AC-coupled, sinusoidal waveform from the communication signals received over the interconnect 106. As before, the decoded information is transmitted to the principal components, as indicated by the reference number 516. The signal detector 502 includes an op amp 702, a capacitor 704, a rectifier, or diode, 706, a resistor 708 and an inverter 712. The negative input of the op amp 702 is connected to the resistor 708. The resistor 710 is connected between the capacitor 704 and the conductor 110. The rectifier, or diode, 706 is connected between the output of the op amp 702 and the negative input of the op amp 702. The positive input of

the op amp 702 is connected to a capacitor 704, which is itself connected to the second conductor 108. The inverter 712, such as one having hysteresis, is connected between the first conductor 110 and the principal components, as indicated by the reference number 516.

Method

FIG. 8 shows a method 800 for transmitting information between the electronic device 102 and the power supply 104 over the interconnect 106, according to a specific embodiment of the invention. For instance, power parameters are encoded by the electronic device 102 into a series of high-frequency pulses (802). The high-frequency pulses may be a pulse-width modulated (PWM) waveform, a triangular waveform, a square waveform, a sinusoidal waveform, or another type of waveform. For example, where the high-frequency pulses are a PWM waveform, the power parameters are pulse-width modulated by the electronic device 102 into the pulses. The series of high-frequency pulses is transmitted over the interconnect 106 by the electronic device 102 (804).

The series of high-frequency pulses is then received by the power supply 104 for the electronic device 102 over the interconnect 106 (806). The power supply 104 decodes the power parameters from the series of high-frequency pulses (808). The power supply 104 may thus convert alternating current (AC) direct current (DC) to DC or AC according to these power parameters, for transmission over the interconnect 106 (810).

The power supply 104 also may itself encode information in a series of high-frequency pulses (812). This series of high-frequencies pulses is also transmitted over the interconnect 106 (814). The electronic device 102 receives the series of high-frequency pulses over the interconnect 106 (816), and decodes the information from the series of pulses (818). Information can thus be transmitted from the electronic device 102 to the power supply 104, and/or from the power supply 104 to the electronic device 102.

Furthermore, the series of high-frequency pulses may be isolated from the primary components 206 within the electronic device 102 (820), as well as

from the primary components 224 within the power supply 104 (822). For example, in FIG. 2, the inductor 208 of the electronic device 102 isolates the high-frequency pulses from significantly affecting or being significantly transmitted to the principal components 202 of the device 102. Similarly, in FIG. 2, the inductor 226 of the power supply 104 isolates the high-frequency pulses from affecting or being transmitted to the principal components 224 of the power supply 104.

Conclusion

It is noted that, although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This application is intended to cover any adaptations or variations of the disclosed embodiments of the present invention. Therefore, it is manifestly intended that this invention be limited only by the claims and equivalents thereof.